



**Intermountain Power Service**

**Delta, Utah**

**Technical Audit Report**

**Demineralizer System**

**October 8, 2008**

**By**

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## **Intermountain Power Service**

### **Delta, Utah**

## **Technical Audit Report**

### **Executive Summary**

Findings and recommendations (in the order presented in the report)

#### **Design Review**

1. The primary cation, when operated at 300 gpm (RO constricted flow rate) has an area flow of 3.2 gpm/ft<sup>2</sup>, below the industry minimum of 5.0 gpm/ft<sup>2</sup>.

►<sup>1</sup> Investigate the design of the vessel inlet distributors to determine if they will still be effective at this low flow.

2. On the other hand, the primary anion (weak base), the secondary cation, and both the polishing cation and anions, when operated at 650 gpm, the design fast rinse flow rate (which is not RO constricted), has an area flow loading of 11.5 gpm/ft<sup>2</sup>, which is above the industry maximum of 10 gpm/ft<sup>2</sup>.

► Calibrated inlet and outlet pressure gauges are needed on all the vessels in this system to monitor pressure drop during fast rinse steps. High DP can lead to resin attrition by crushing.

#### **Regeneration Review**

3. All the vessels have backwash times set at 10 minutes. This is likely adequate for all the beds except for the primary cation. Any particulates coming into the demin system will be filtered out by this lead vessel, which would require a longer backwash.

► Increase the duration of the primary cation backwash to 30 minutes.

4. Due to the switch to RO pretreatment, the acid profile of 2-4-6% sulfuric is likely no longer needed. In addition, the dilute acid flow rate is at the lower end of industry best practice.

► A 1%-6% profile would simplify the regeneration requirements. The low acid flow may prove adequate for the permeate inlet chemistry.

5. The secondary and polisher anion regenerations suffer from the lack of a bed preheat step needed for optimal silica removal.

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<sup>1</sup> Action items are identified with the black arrow in the margin, both in this summary and in the detailed report.

► Add a 40-minute bed preheat using warmed dilution water with no caustic.

6. The secondary and polisher anion are regenerated with 3% NaOH. Better silica chemistry would be obtained with 4% NaOH, which is the standard of the industry.

► Change NaOH concentration from 3 to 4% for both secondary anion and polisher anion.

#### **Eluion Study (Field Measurements during Regeneration of Train B)**

7. There appeared to be extensive operator intervention in the controlling of flow rates during the vessel backwashes. This should be a totally automatic step under the control of the regeneration program.

► Check operation and settings for back wash outlet (BWO) valves. They should be adjustable diaphragm valves with the large screw-type adjustment available to limit the flow through the valve.

8. The acid and caustic dilution systems, particularly the acid system, could not furnish the required steady strengths of acid and caustic, despite intense intervention from the lab tech. High concentration alarms shut the regeneration down twice.

► The acid and caustic dilution systems need to be replaced with ones more reliable and easier to control. The new systems should also incorporate data logging to record flows and concentrations for archiving.

9. The current operation of the regeneration program produced several system shutdowns. Alarm settings need to be checked, as well as system response to the problem.

► Review alarm settings, particularly for acid and caustic concentration ranges. Consider using a low/low low and high/ high high approach with the low and high alarms generating an alarm but not shutting the regeneration down. A shutdown with sulfuric acid still in the cation vessels is particularly dangerous. The high high setting could be for a shutdown.

10. The highest acid concentration achieved in the secondary cation effluent was only 4%. The highest from the primary cation was only 2%. 2% will not properly regenerate the lead cation bed for Na. We suspect some laterals are facing up into the headspace above the bed instead of directly at the bed.

► Check the operation of the acid distributors which are just above the bed. Drain the vessels to bed level and initiate dilution water flow (no acid!). Observe the spray pattern for any irregularities.

11. The primary cation fast rinse was retarded, i.e., prolonged in time. This is a typical symptom of cation hardness fouling. Analysis of recent resin samples from 1A and 1B showed very high concentrations of Ca and off-scale concentrations of Mg. The fouling was likely caused by the erratic acid dilution system. (Only one or two improper regens are enough to foul a bed.)

► Have the primary cation resins professionally cleaned by RTI to remove all the hardness fouling. Once cleaned, with the RO feed it is unlikely they will ever need cleaning again.

12. The absence of a bed preheat step results in one quarter of the caustic dosage going to the secondary anion below the optimal temperature of 120°F. This, plus the sub-optimal 3% concentration, could cause silica capacity and leakage problems.

► Before any recommendations for anion NaOH injection are made, the silica and conductivity leakage project needs to be completed (see below). This will determine silica breakthrough vs. conductivity breakthrough, and allow the plant to determine if better silica handling is required in the demins.

► If a change in the caustic injection particulars is required, a better dilution water heating system would be required. The current method uses on-demand electrical heating, which held up the caustic injection for several minutes. A better approach would be to have a tank of pre-warmed water available prior to regeneration, using the current heaters as temperature trim.

13. The highest concentration of caustic seen out of the secondary anion was only 2.1%, whereas the lab technician was reporting 3% by Baumé readings at the caustic dilution station.

► Investigate the source of the dilution effect seen in both the acid and caustic injections.

#### 14. Summary of Step Time Changes

The following changes are based on observed conductivity values, not theoretical.

Regeneration Step	Current Timer, minutes	Recommended minutes
		(no entry is no change)
Sec An BW	10	
Settle	3	
Sec Cat BW	10	

Settle	3	
Prim An BW	10	
Settle	3	
Leg Total	39	
Sec An NaOH	50	
Series An NaOH	40	
Series An Slow Rinse	140	40
Leg Total	230	120
Prim Cat BW	10	30
Settle	3	
2% Series Cat Acid	28	
4% Series Cat Acid	9	
6% Series Cat Acid	6	
Series Cat Slow Rinse	20	
Prim Cat Fast Rinse	90	30
Leg Total	166	106
Wait: should be	24	
Wait: actual	64	
Prim An Fast Rinse	75	30
Prim C/A Recycle	40	(consider eliminating)
Sec An Fast Rinse	30	
Sec C/A Recycle	40	(consider eliminating)
Prim/Sec Recycle	40	
Leg Total	225	100

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Regen Total

494 (8 hrs, 14 min.)

365 (6 hrs, 5 min.)

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15. A dissolved oxygen test method was given for monitoring the performance of the vacuum degasifier.

16. A recent round of resin analysis identified no serious "red flags." Hardness fouling was missed because the analyzing lab only does hardness on request.

### **Prioritization**

The most fundamental question we have for IPSC is the following: Is the plant satisfied with current water quality from the demins, i.e., are silica values in the boilers and steam acceptable, are the current cycles of concentration acceptable, is steam cation conductivity acceptable? Put another way, does IPSC want less risk in cycle chemistry or is the current level of risk (as assessed by EPRI standards) satisfactory? Is the current consumption of acid and caustic acceptable? If any of these questions are answered in the negative, many areas for immediate system improvement have been discovered in this project with various investments of time and money, but with predictable rewards for IPSC in terms of lower cost of operation and decreased chemistry risks.

If IPSC wants to move forward in the water plant, we suggest the following prioritized items for action:

(1) High priority, modest investment of money, no plant time: have RTI clean 1A and 1B for heavy hardness fouling.

(2) High priority, low time or money investment:

- Change step times in regeneration program
- Synchronize step numbering between Modicon and operator screens
- Go to 1% - 6% acid profile (once resins are cleaned, this will keep them clean)

(3) High priority, almost no investment of time or money: Silica and Conductivity Profile Project with Norm Hess of GE Betz.

- Daily or every other day sampling for low level silica, sodium, and conductivity out of primary cation, Vac Degas sump, secondary cation and anion
- Record conductivities at Vac Degas sump and secondary anion

After several weeks of data, this will establish silica breakthrough profile and conductivity breakthrough profile, telling us whether the 3% NaOH and lack of bed preheat are important



enough to correct. It will also help establish a new post-RO demin throughput target, and tell us if on-line silica analyzers would be helpful.

(4) Medium priority, large investment of time and money:

- Develop engineering specifications for new acid and caustic dilution stations (consider only one new station, shared by each train) and let project for bid, or
- Contract with OEM to do the entire project for IPSC. *Lane Christensen*

(5) Low priority, almost no investment of time or money: determine spray pattern of regenerant distributors in primary and secondary vessels. This could be source of acid and caustic dilution.

(6) Low priority, modest investment of time and money: update the Modicon "brain" controlling the regeneration steps.

On behalf of RTI, we wish to thank Don Smith of IPSC who made this project possible. We also want to thank the many operators we spoke with and worked with while on-site. Amy in the lab was particularly helpful. Everyone was highly co-operative, eager to answer questions about the system, and equally eager to ask questions. Plus, we experienced Utah hospitality and scenery at its finest.

For RTI,

William E. Bornak

VP Technology

## **Intermountain Power Service**

### **Delta, Utah**

## **Technical Audit Report**

### **Introduction**

IPS takes makeup water from four on-site wells, roughly 1000 ft deep. Some change in conductivity noted over the years. The temperature of the supply is very stable with only a degree or two difference between summer and winter.

There are two separate demineralization trains. Water from the polishers is sent to one of two DI storage tanks. Each tank is 1 MM gallons. One tank is kept full; the other fluctuates down to 20 feet. The tanks are rotated every six months.

There are also two condensate storage tanks, each 200K gallons, one for each generating unit. There are condensate polishers, which are usually not used due to an on-going iron problem.

Each demin train consists of the following: Primary Cation/Primary Anion/Vacuum Degasifier/Secondary Cation/Secondary Anion/Polishing Cation/Polishing Anion.

The vacuum degasifier is a two stage design.

Operating conductivity is measured at the following key spots:

- Vacuum degasifier sump outlet
- Secondary anion outlet, and
- Polisher anion outlet

## Design Review

RTI uses a templated design process which compares key vessel geometries and regeneration practices against industry best practices. This section will be followed by the on-site measurements taken from an actual regeneration. In the following tables items in **red bold** are considered out of compliance and are reviewed after each table. Please understand: this review is not intended to be negative. Most items in the tables are in compliance and do not need discussion. Focusing on the out-of-compliance items, however, identifies areas for system improvement.

### Primary Cation and Primary Anion

#### Demineralizer Audit

<b>Customer</b>	Intermountain Power Service		
<b>Location</b>	Delta, UT		
<b>Review Date</b>	10/5/2008		
<b>System:</b>	Vessels are arranged:		
	Primary Cation	<b>PreTreat.</b>	
# WAC	0	Primary Anion (Weak Base)	On-site
# SAC	6	Vac	wells
D/G	2	Degasifier	
# WBA	3	Secondary Cation	
# SBA	3	Secondary Anion (SBA)	
# M/B	0	Polisher Cation	
		Polisher Anion (SBA)	

#### Trains A and B

#### FLOW ANALYSIS

Primary Cation		Amberlite IR-120 Plus				
OD, inches	Area, SF	Max gpm at 10 gpm/SF	Min gpm at 5 gpm/SF			
132	95	950	475			
SS, inches	Max bed ft. at 100% FB+B54	Max bed in. at 100% FB				
135	5.6	67.5				
Resin bed Volume, CF	Bed Depth feet	Bed Depth inches	Required Freeboard feet	Required Freeboard inches	Required Straight Side feet	Required Straight Side inches
491	5.2	62	5.2	62	10	124
Design Flow Max gpm	Design Max gpm/SF	Design Max gpm/CF				

650	6.8	1.3
Design Flow Min gpm 150	Design Min gpm/SF 1.6	Design Min gpm/CF 0.3
Actual Flow Max gpm 300	Actual Max. gpm/SF 3.2 [5 - 10]	Actual Max. gpm/CF 2.0
Actual Flow Min gpm 100	Actual Min. gpm/SF 1.1	Actual Min. gpm/CF 0.2

#### Concerns:

(1) The new RO has forced the maximum flow loading on either train down to 300 gpm. This is below the nominal minimum flow loading used in the industry, which is 5 gpm/ft<sup>2</sup>. There is no consequence to the resin chemistry from this, but there is a challenge to the inlet distributors to work so close to their lower design end.

The problem with a distributor working at its low end is the potential for channeling. Proper distribution requires flow throughout the distributor assembly. We do not know what type of distributor is used here. Some types can tolerate operation beyond normal flow limits; others will show hydraulic problems. This needs to be investigated.

► Identify type of inlet distributors on all six vessels. Determine sensitivity to operation at 300 gpm.

#### Flow Analysis - continued

Primary Anion		(Weak Base)	Amberlite IRA-94			
OD, inches	Area, SF	Max gpm at 10 gpm/SF	Min gpm at 5 gpm/SF			
102	57	567	284			
SS, inches	Max bed ft. at 100% FB	Max bed in. at 100% FB				
147	6.1	73.5				
			Required	Required	Required	Required
Resin bed	Bed Depth	Bed Depth	Freeboard	Freeboard	Straight Side	Straight Side

Volume, CF 262	feet 4.6	Inches 55	feet 4.6	inches 55	feet 9	inches 111
Design Flow Max gpm 650	Design Max gpm/SF 11.5 [5 - 10]	Design Max gpm/CF 2.5				
Design Flow Min gpm 150	Design Min gpm/SF 2.6	Design Min gpm/CF 0.6				
Actual Flow Max gpm 300	Actual Max. gpm/SF 5.3	Actual Max. gpm/CF 2.0				
Actual Flow Min gpm 150	Actual Min. gpm/SF 1.6	Actual Min. gpm/CF 0.3				

The concern for the primary anion is the opposite of that in the cation. In this case we would be concerned about the flow loading at 650 gpm, but the system is constrained by the installation of the RO to operate at 300 gpm.

### Secondary Cation and Anion

Trains A and B		FLOW ANALYSIS				
Secondary Cation		Amberlite IR-120 Plus				
OD, inches 96	Area, SF 50	Max gpm at 10 gpm/SF 503	Min gpm at 5 gpm/SF 251			
SS, inches 81	Max bed ft. at 100% FB+B54 3.4	Max bed in. at 100% FB 40.5	75 CF subfill			
Resin bed Volume, CF 146	Bed Depth feet 2.9	Bed Depth inches 35	Required Freeboard feet 2.9	Required Freeboard inches 35	Required Straight Side feet 6	Required Straight Side inches 70

Design Flow Max gpm 650	Design Max gpm/SF 12.9 [5 - 10]	Design Max gpm/CF 4.5
Design Flow Min gpm 150	Design Min gpm/SF 3.0	Design Min gpm/CF 1.0
Actual Flow Max gpm 300	Actual Max. gpm/SF 6.0	Actual Max. gpm/CF 2.0
Actual Flow Min gpm 150	Actual Min. gpm/SF 3.0	Actual Min. gpm/CF 1.0

The same comment applies to the secondary cation that was mentioned in the primary anion: under design max flow, the flow loading is above industry best practices. Luckily the RO constrains operation to 300 gpm. In the field study presented after this review section, we confirmed that the fast rinse flows are indeed 650 gpm.

#### Flow Analysis - continued

Secondary Anion		(Strong Base)		Amberlite IRA-402		
OD, inches 120	Area, SF 79	Max gpm at 10 gpm/SF 785	Min gpm at 5 gpm/SF 393			
SS, inches 122	Max bed ft. at 100% FB 5.1	Max bed in. at 100% FB 61				
			Required	Required	Required	Required
Resin bed Volume, CF 361	Bed Depth feet 4.6	Bed Depth inches 55	Freeboard feet 4.6	Freeboard inches 55	Straight Side feet 9	Straight Side inches 110
Design Flow Max gpm 650	Design Max gpm/SF 8.3	Design Max gpm/CF 1.8				
Design	Design Min	Design Min				

Flow		
Min gpm	gpm/SF	gpm/CF
150	1.9	0.4
Actual		
Flow	Actual Max.	Actual Max.
Max gpm	gpm/SF	gpm/CF
300	3.8	2.0
Actual		
Flow	Actual Min.	Actual Min.
Min gpm	gpm/SF	gpm/CF
150	3.0	1.0

There are no items to note on the secondary anion design.

### Polishing Cation and Anion

Trains A and B		FLOW ANALYSIS				
Polishing Cation			Amberlite IR-120 Plus			
OD, inches	Area, SF	Max gpm at 10 gpm/SF	Min gpm at 5 gpm/SF			
96	50	503	251			
SS, inches	Max bed ft. at 100% FB+B54	Max bed in. at 100% FB				
81	3.4	40.5				
Resin bed Volume, CF	Bed Depth feet	Bed Depth inches	Required Freeboard feet	Required Freeboard inches	Required Straight Side feet	Required Straight Side inches
146	2.9	35	2.9	35	6	70
Design Flow Max gpm	Design Max gpm/SF 12.9 [5 - 10]	Design Max gpm/CF 4.5				
Design Flow Min gpm	Design Min gpm/SF 3.0	Design Min gpm/CF 1.0				
150						
Actual Flow Max gpm	Actual Max. gpm/SF 6.0	Actual Max. gpm/CF 2.0				
300						

Actual Flow Min gpm	Actual Min. gpm/SF	Actual Min. gpm/CF
150	3.0	1.0

Graver is nothing if not consistent in their design philosophy used for this system. At nominal max flow of 650 gpm, the flow loading on the resin bed is above industry best practice. Again, as with the preceding vessels, the RO will constrain operation to 300 gpm except during regenerations.

### Flow Analysis - continued

Polishing Anion		(Strong Base)	Amberlite IRA-402			
OD, inches	Area, SF	Max gpm at 10 gpm/SF	Min gpm at 5 gpm/SF			
96	50	503	251			
SS, inches	Max bed ft. at 100% FB	Max bed in. at 100% FB				
81	3.4	40.5				
Resin bed Volume, CF	Bed Depth feet	Bed Depth inches	Required Freeboard feet	Required Freeboard inches	Required Straight Side feet	Required Straight Side inches
146	2.9	35	2.9	35	6	70
Design Flow Max gpm	Design Max gpm/SF	Design Max gpm/CF				
650	12.9	4.5				
Design Flow Min gpm	Design Min gpm/SF	Design Min gpm/CF				
150	3.0	1.0				
Actual Flow Max gpm	Actual Max. gpm/SF	Actual Max. gpm/CF				
300	6.0	2.0				
Actual Flow Min gpm	Actual Min. gpm/SF	Actual Min. gpm/CF				
150	3.0	1.0				



The comments from the polishing cation also apply here.

### Regeneration Review

There are two parts to this review: the design regeneration protocol and the actual as-measured protocol. The design review is presented first, again using a templated approach to each vessel.

#### Primary Cation Regeneration Design

##### REGENERATION ANALYSIS -- Primary Cation

###### Backwash

Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons
620	6.52	60 F		10 (depends)	6200

###### First Acid

Flow, gpm	gpm/CF	Design %:	Actual %	lbs/gallon	Duration	Step Gallons	Total Acid
248	0.51		2	0.1689	18	4464	754

###### Second Acid

Flow, gpm	gpm/CF	Design %:	Actual %	lbs/gallon	Duration	Step Gallons	Total Acid	
251	0.51		4	0.3422	9	2259	773	pounds

###### Third Acid

Flow, gpm	gpm/CF	Design %:	Actual %	lbs/gallon	Duration	Step Gallons	Total Acid	
254	0.52 [0.5 - 1.0]		6	0.52	6	1524	792	pounds

Total Acid	2319	pounds
<b>Total Acid/CF</b>	<b>4.72</b>	<b>dosage</b>

###### Displacement Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
245	0.50	14	3430

###### Fast Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
650	1.32	26	16900

###### Rinse Recycle

Flow, gpm/CF	Duration	Step Gallons

gpm

650 1.32

40

26000

(not included in total)

Total Regeneration Gallons	34777
Total Rinse Gallons	16900
Total Rinse, Gallons per C. F.	34

(1) We do not know if 10 minutes is an adequate backwash time for this inlet water. Much depends on inlet turbidity, which, from a well supply, should be quite low.

(2) We also note that the dilute acid velocity (gpm/ft<sup>3</sup>) is exactly at the low end of the range normally used in industry, which is 0.5 to 1.0 gpm/ft<sup>3</sup>. In light of the high calcium loading on the resin and the use of sulfuric acid as a regenerant, we would suggest raising the acid flow rate to mid range.

Actually, this becomes imperative. The cation resin analysis (see end of elution study), which showed extremely high levels of Ca fouling. Ca fouling is produced during the first acid step if the concentration of acid is too high and/or the flow rate is too low.

► Raise dilute acid velocity to primary (and secondary) cations to 0.75 gpm/ft<sup>3</sup>. Lower the concentration of the first step to 1%.

### Primary Anion Regeneration Design

#### REGENERATION ANALYSIS -- ANION

co-current

##### Backwash

Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons
140	1.47	60F		10	1400

NaOH Injection		Design %:	3	@ 95F			
Flow, gpm	gpm/CF	Actual %	lbs/gallon	Duration	Step Gallons	Total NaOH	pounds
78.2	0.30	3	0.2583	82	6412.4	1656	

Total NaOH	1656	pounds
<b>Total NaOH/Cubic foot</b>	6.32	<b>dosage</b>

##### Displacement Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
75	0.29	26	1950

##### Fast Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
650	2.48	30	19500

**Recycle Rinse**

Flow, gpm	gpm/CF	Duration	Step Gallons	
650	2.48	40	26000	(not included in total)

Total Regeneration Gallons	29262
Total Rinse Gallons	19500
Total Rinse, Gallons per Cubic Foot	74
	[45 - 75]

The primary anion is regenerated in a thoroughfare fashion, which means the caustic is injected into the secondary anion first, and the effluent from this vessel is sent to the primary anion. The first fraction of caustic from the secondary is discarded, as explained below in that section of this review.

Here the only item of note is that the design total rinse volume is very close to that normally encountered with anion resins. This is not a major item. Nor is the overall dosage of caustic. The chemistry of the weak base resin is quite different than that of the strong base. The strong base resin requires an overdose of caustic to get reasonable capacity from the resin. The weak base resin, on the other hand, regenerates "stoichiometrically," that is, virtually complete with any reasonable dosage. Thus, the total dosage reflects the total capacity of the resin.

**Secondary Cation Regeneration Design****REGENERATION ANALYSIS -- CATION****Backwash**

Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons
325	6.47	60 F		10	3250

**First  
Acid**

Flow, gpm	gpm/CF	Design %:	Actual %	Expansion lbs/gallon	Duration	Step Gallons	Total Acid
83	0.57	6	6	0.52	20	1660	863

Total Acid 863 pounds  
Total Acid/CF 5.91 dosage

**Displacement Rinse**

Flow, gpm	gpm/CF	Duration	Step Gallons
80	0.55	16	1280

**Fast Rinse**

Flow, gpm	gpm/CF	Duration	Step Gallons
--------------	--------	----------	-----------------

250	1.71	20	5000
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#### Recycle rinse

Flow, gpm	gpm/CF	Duration	Step Gallons	(not included in rinse total)
650	4.45	40	26000	
Total Regen Gallons			11190	
Total Rinse Gallons			5000	
Total Rinse, Gallons per C. F.			34	

The duration of the slow rinse is slightly under what would normally be required for this resin. The final decision on step times, however, must be reserved for the presentation below of the actual field measured conductivities.

### Secondary Anion Regeneration Design

#### REGENERATION ANALYSIS -- Secondary Anion co-current

##### Backwash

Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons
235	4.68	60 F		10	2350

##### Bed Preheat

Flow, gpm	gpm/CF	Temp	Duration	Step Gallons
	0.00		none	

##### NaOH Injection

Flow, gpm	gpm/CF	Design %:	lbs/gallon	Duration	Step Gallons	Total NaOH	
72	0.20	3	0.2583	82	5904	1525	pounds

Total NaOH	1525	pounds
<b>Total NaOH/Cubic foot</b>	4.22	<b>dosage</b>

##### Displacement Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
112	0.31	24	2688

##### Fast Rinse

Flow, gpm	gpm/CF	Duration	Step Gallons
650	1.80	55	35750

##### Secondary Rinse Recycle

Flow, gpm	gpm/CF	Duration	Step Gallons	(not included in total)
650	1.80	30	19500	
<b>Mandatory Rinse Recycle</b>				
Flow, gpm	gpm/CF	Duration	Step Gallons	(not included in total)
650	1.80	42	27300	
Total Regeneration Gallons			46692	
Total Rinse Gallons			35750	
Total Rinse, Gallons per Cubic Foot			99	
			[45 - 75]	

(1) There is a big problem with this regeneration in that it lacks a bed preheat step. For optimal silica capacity and leakage, a strong base resin needs a good dosage of caustic, optimally at 4% and optimally at 120°F. In this case the dosage appears to be right, if perhaps slightly low, but the concentration and temperature are off.

A bed preheat sends 120°F dilution water to the strong base resin for about 40 – 45 minutes. This heats up the piping, valving, resin, and vessel to 120°F before the NaOH injection starts. Otherwise, the first fraction of caustic is injected at a less than 120°F temperature as the warm caustic has to do the work of heating the system components up to 120°F. The best regeneration has the entire fraction of caustic going into the vessel at the target temperature.

► Change the Modicon program to include a 40 minute bed preheat step in which 120°F dilution water is injected into the secondary anion. It can go to waste; there is no need to thoroughfare it to the primary, since the weak base's chemistry does not need heat.

(2) The overall design rinse requirement is very high. We do not know why the OEM set the rinse at such a high volume. This will be discussed further in the field studies section below.

#### Polishing Cation Regeneration Design

*Regen every 12 months*

#### REGENERATION ANALYSIS -- Polishing Cation

##### Individual Regeneration

##### Backwash

Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons
325	6.47			10	3250

<b>Acid</b>		Design %:	6			
Flow, gpm	gpm/CF	Actual %	lbs/gallon	Duration	Step Gallons	Total Acid
83	0.57	6	0.52	26	2158	1122

				Total Acid	1122	pounds
				<b>Total Acid/CF</b>	<b>7.69</b>	<b>dosage</b>
<b>Displacement Rinse</b>						
Flow,				Duration	Step Gallons	
gpm	gpm/CF					
80	0.55			16	1280	
<b>Fast Rinse</b>						
Flow,				Duration	Step Gallons	
gpm	gpm/CF					
250	1.71			20	5000	
Total Regeneration Gallons				11688		
Total Rinse Gallons				5000		
Total Rinse, Gallons per C. F.				34		

*10 lbs Recommended*

(1) The total acid dosage of 7.7 lbs/ft<sup>3</sup> may actually be low for a polisher. Most mixed bed cation components are regenerated at 10 lbs/ft<sup>3</sup>. This vessel is regenerated so infrequently that it probably does not matter. If water quality coming from the polishing section of the demin system ever proves to be unacceptable, one of the first changes which could be made is to raise the dosage of acid to 10 lbs/ft<sup>3</sup>.

(2) We are also leery of the short duration of the displacement rinse, although industry standard practice is only 20 – 30 minutes, not much of a savings in time or water. We defer to the field measurements, discussed below.

### Polishing Anion Regeneration Design

*Regen every 12 months*

REGENERATION ANALYSIS -- Polishing Anion					co-current		
Backwash							
Flow, gpm	gpm/SF	Temp.	Expansion %	Duration	Step Gallons		
150	2.98			10	1500		
Bed Preheat							
Flow, gpm	gpm/C F	Temp		Duration	Step Gallons		
	0.00			none			
NaOH Injection							
		Design %:	3	@120F			
Flow, gpm	gpm/C F	Actual %	lbs/gallon	Duration	Step Gallons	Total NaOH	
38.6	0.26	3	0.2583	82	3165.2	818	pounds
Total NaOH						818	pounds
Total NaOH/Cubic foot						5.60	dosage
Displacement Rinse							
Flow,	gpm/C			Duration	Step		

*10 lbs Recommended*

gpm	F		Gallons	
112	0.77	11	1232	
<b>Fast Rinse</b>				
Flow, gpm	gpm/C	Duration	Step Gallons	
300	2.05	50	15000	
<b>Recycle Rinse</b>				
Flow, gpm	gpm/C	Duration	Step Gallons	
	F			(not included in total rinse)
650	4.45	40	26000	
Total Regeneration Gallons			20897	
Total Rinse Gallons			15000	
Total Rinse, Gallons per Cubic Foot			103	
			[35 - 75]	

(1) We also note the absence of a bed preheat step for the polishing anion, although we would suggest that this is not so critical as the need for the preheat step in the secondary anion regeneration, where it is critical.

We have embarked on a silica monitoring project with GE Betz to monitor several parameters over time during the service phase of this demin's operation. When the RO was installed, there was a major change in the chemistry which the resins in this system are exposed to. At the same time, there was no change in the regeneration practices. We need to know the level of silica, sodium, and hardness which the primary and secondary resins are "seeing" during the service run. The monitoring project should provide these details. Based upon the observed chemistry, there may be a need for major changes in the regeneration protocols.

(2) The overall caustic dosage might be proven too light for the actual silica loading in the polishers. Again, this decision would await the results of the monitoring project.

(3) It is highly unusual for an OEM to deliberately design so high a total rinse dosage to the anion resins.

## Regeneration Monitoring – “Elution Study”

The word *elution* refers to the removal of material from a column of absorbent. In ion exchange, it refers to the removal of service ions from a column of resin during the process of regeneration. When warranted, measurements of Ca, Na, Mg, etc. can be monitored during the acid injection and rinse steps to construct “elution curves” for each species. That is rarely needed in industrial water treatment and would be more likely to show up in specialized, non-water-treatment resin applications.

The word now refers to a project in which the inlet and outlet regenerant concentrations are measured, rather than eluted ions, and that is the more modern usage. We prefer *regeneration project* or *engineering study*.

### Complexity of Regeneration

We start this review with the following observation: **this is the most complicated regeneration protocol the author has ever seen in some 40 years of practice.** It was difficult to ensure samples were being taken from the right vessel, flows were hard to monitor, etc., and the entire project was almost compromised by at least three automatic regeneration shut-downs initiated by the control program.

Operators told us before the engineering study that the regeneration was problematic and Don Smith indicated that some operators will not attempt a regeneration except with a lab technician to monitor acid and caustic concentrations, as well as a programming expert to recover from system shutdowns by directly accessing the Modicon. We were skeptical of the need for these extra people, as most other systems are regenerated by a single operator, but when we saw how this system behaved during a regeneration, we now understand why some operators are leery of doing a regeneration alone.

### Cation Regeneration

The basic steps of a cation regeneration are:

- Backwash to remove particulates and loosen up the resin
- (Optional settle step)
- Acid injection at various concentrations (when using  $H_2SO_4$ )
- Displacement or slow rinse
- Fast or final rinse

This system also employs several rinse recycles in which anion effluent is sent back to the corresponding cation or to the primary cation at the front end of the system.



In the following data graphs, the concept of “regeneration time” is used. The author uses this metric to highlight the acid (or caustic) injection step and to de-emphasize the backwash and settle steps. **Regen “time zero” is when the acid or caustic pumps are**



**engaged.** This also allows us to synchronize the two simultaneous “legs” of the regeneration, as discussed directly below.

Due to the complexity of the regeneration, we need a step time diagram. (A similar one is in the water plant control room.) This is shown in the table below:

**Regeneration Step Times and Sequences**

		Sec An BW	10		
		Settle	3		
		Sec Cat BW	10		
		Settle	3		
		Prim An BW	10		
		Settle	3		
		Leg Total	39		
Sec An NaOH	50			Prim Cat BW	10
Series An NaOH	40			Settle	3
Series An Slow Rnse	140			2% Series Cat Acid	28
Leg Total	230			4% Series Cat Acid	9
				6% Series Cat Acid	6
				Series Cat Slow Rinse	20
				Prim Cat Fast Rinse	90
				Leg Total	166
				Wait: should be	24
				Wait: actual	64
					
		Prim An Fast Rinse	75		
		Prim C/A Recycle	40		
		Sec An Fast Rinse	30		
		Sec C/A Recycle	40		
		Prim/Sec Recycle	40	“Mandatory Recycle”	
		Leg Total	225		
		Regen Total	494	8 hours 14 min.	

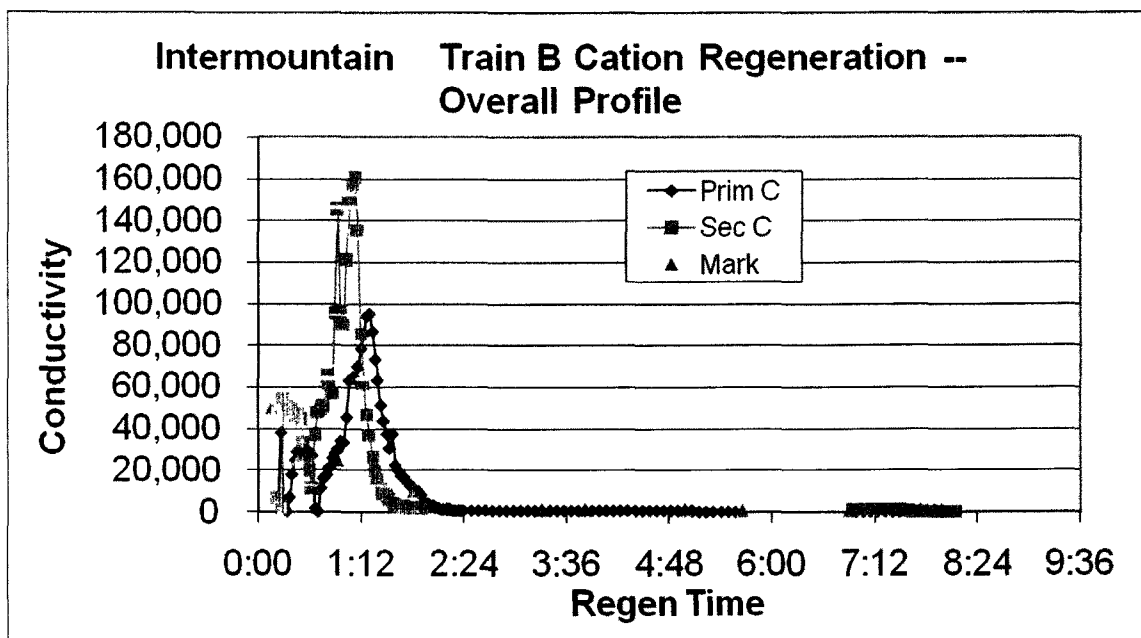
In addition to the listed time, some operators put the various fast rinses into an arbitrary “prolong” option, adding 30 – 40 minutes to reach present conductivity targets.

We review the data from the cation regenerations first. The B Train was regenerated, primary and secondary vessels only, not the polishers. All the field data can be found in Appendix 1.

Although the backwash steps are not shown in the graphs below, we did observe a high level of operator involvement in setting the rates for these steps. It stood out only because most other systems we have seen have a pre-set backwash flow rate, set by a variable diaphragm valve on the backwash outlet line. In this system the BWO (backwash outlet) diaphragm at the top of the units seems to be on/off rather than

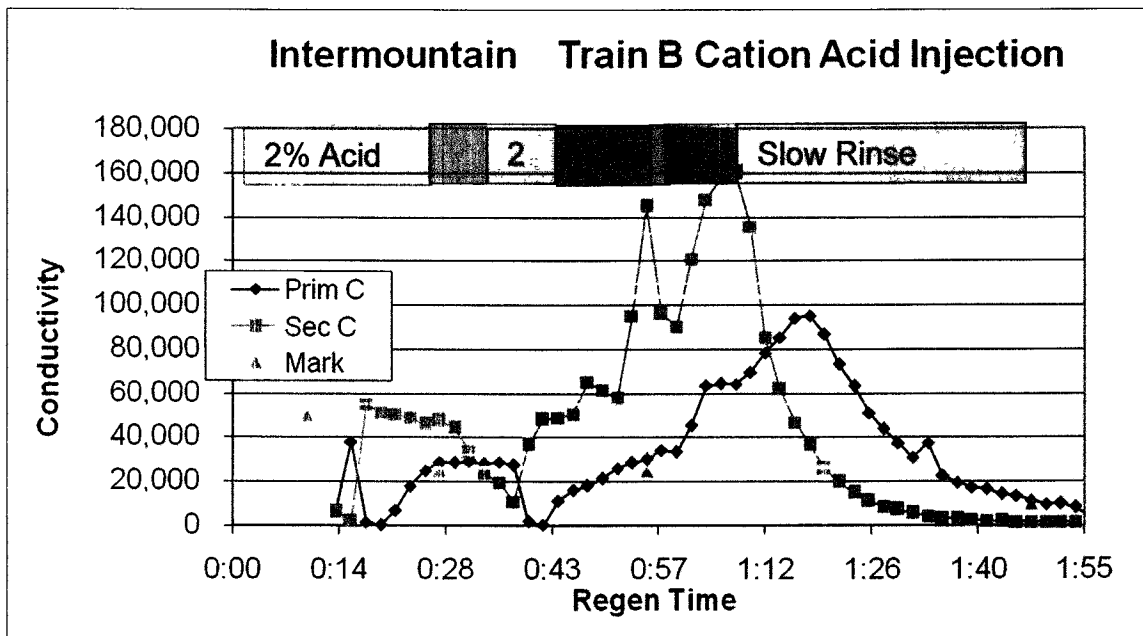
regulating. Regulation was provided by manual valves at grade level in the outlet line and this required operator involvement to set the flow rate.

The first graph is the overall conductivity measurements taken during the entire regeneration of primary and secondary.



Not much detail can be seen in the overall profile, so each section of the regeneration is taken from the overall graph using a time expansion of the X-axis.

The first step of interest is the acid injection steps, shown below. **The gray boxes are the system shutdowns due to a high acid concentrations.**



We have tried our best to represent the acid profile going into the secondary cation and the slow rinse by the colored text boxes at the top of the chart, including the gray boxes representing the system shutdowns. However, we cannot be sure the box ends correspond to exactly when the steps changed. (The orange triangles are major step marks we think the system was showing during the study.) There was great confusion as to when the regeneration actually re-started after the shutdowns. There are several items of which we are sure:

(1) The acid dilution system is very difficult to control. We would go further and characterize it as “out of control.” The lab tech tried to manually adjust the acid at each step, either overshooting or undershooting the required concentration. We need to point out the criticality of having the acid strength under control. The danger for  $\text{CaSO}_4$  precipitation is ever-present, especially with the low dilute acid flow rate noted earlier. (It has already occurred; see below.) In addition, almost all other demins the author has investigated require relatively little operation intervention, let alone a lab technician (and a programmer).

► Consider a total replacement of the acid dilution station with one with more reliable flow control, high range sulfuric acid concentration meters, and some type of feedback control loop to maintain the required concentrations. RTI can advise from a chemistry standpoint that this is strongly needed, but we cannot advise on the engineering details of the replacement system; that is not our expertise.

(2) The highest conductivity from the secondary was 160,000  $\mu\text{S}$ . 4% sulfuric acid has a conductivity at room temperature of 180,000  $\mu\text{S}$ . Either the dilution system never delivered 6% acid or it was diluted by the low flow rate through the unit.

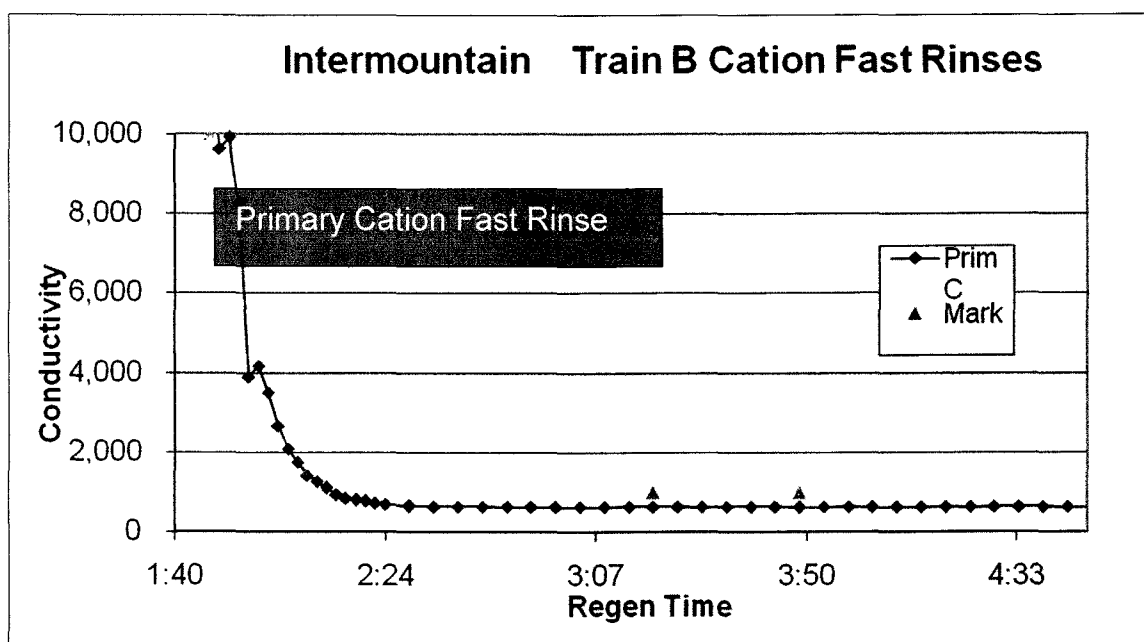
We need to point out that the cation is not drained during acid injection. The acid enters a dedicated lateral just above the bed. The vessel outlet is valved to waste. The inlets are valved off. If the acid flow is too low, however, substantial acid can diffuse above the bed into the water-filled head space. In these vessels there is 100% freeboard in the design (see the design review above). This means there is a volume of space equal to the volume of the resin bed. That is, the top half of the vessel is empty. This is to allow room for bed expansion during backwash. But a sluggish acid flow can allow acid to diffuse up into the water in this head space during the injection, diluting each step.

(3) The acid profile from the primary was worse than the secondary. Maximum acid concentration appears to be just above 90,000  $\mu\text{S}$ , representing just above 2%. This low a concentration can cause a Na problem within the primary cation. It takes 4 – 6% sulfuric acid to strip off the remaining Na service ions from the bed. If they are not removed, two problems can happen during the next service cycle:

- The Na leakage from the cation bed is higher than design, using up secondary cation capacity too quickly, and
- The total run length of the primary cation can be shortened.

Before the installation of the RO, the shortened run would have been quickly noticed. We suggest the current run lengths, up in the millions of gallons (vs. the design throughput of 456,000 gallons on well water), generates a false sense of good demin operation. We suggest that with some system changes the demin could produce much higher volumes of treated water. If the current water balance at the station is adequate for electricity production levels, however, then the current operation might be viewed as totally satisfactory. This is not RTI's call.

The next step in the primary/secondary cation regen is the primary cation fast rinse. This step is timed for 90 minutes, which is much longer than needed. The following graph shows the conductivity from the primary cation during this step:

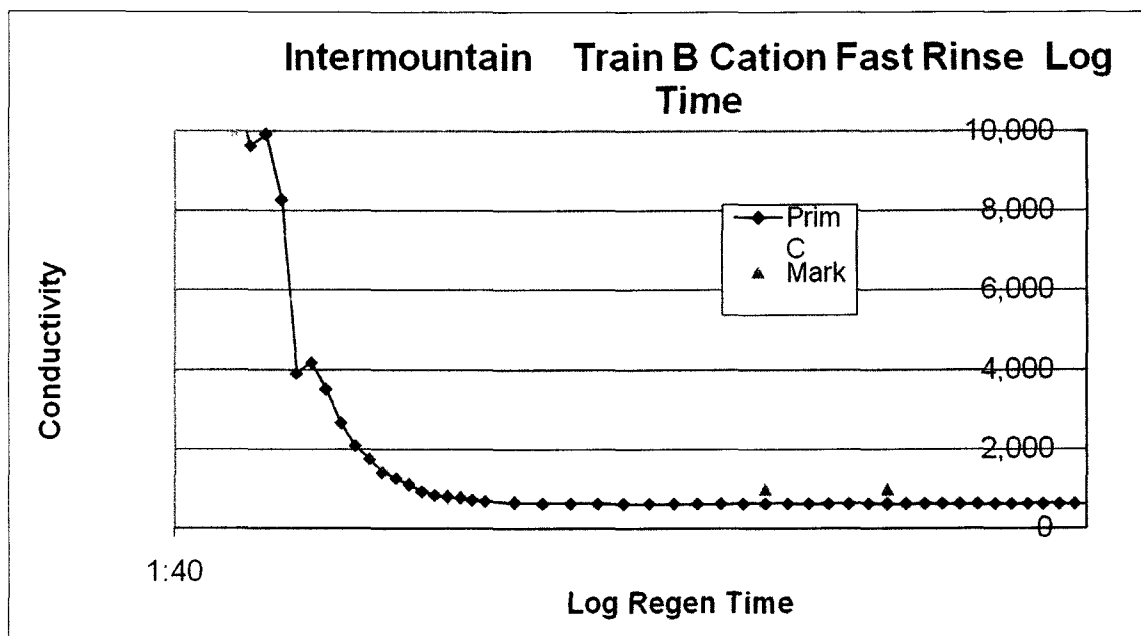


(1) The primary cation fast rinse is fully 90 minutes long. It is very clear from the above graph that the conductivity out of the cation has long since “plateaued” some 33% into the rinse. This means some 60 minutes could be cut from this leg of the regeneration, which is not so significant since the system usually has to wait for the anion leg to catch up. What is significant is the savings in water (60 min x 652 gpm = 39,120 gallons well water), plus the reduced load on the cation. Since well water is being used for this fast rinse, the cation’s freshly regenerated capacity is being used up in this rinse by doing service reactions that would be better put to use in actual service. This also reduces to volume going to waste.

► Reduce primary cation fast rinse to 30 minutes. Normally we make recommendations for regeneration step time changes in small increments. This programming change can be done directly with no small increments.

(2) There is a problem with the initial phase of the fast rinse. Acid rinses out from a cation in an exponential fashion, following normal diffusion kinetics. When an exponential function is plotted in log time, the result is a straight line. Any deviation from a straight line is often an indication that the resin is fouled. This is true for both cation and anion resins.

The graph below shows the above fast rinse plotted against log regen time:



We note that the initial part of the cation fast rinse remains exponential. This confirms that something is impeding the normal diffusion of acid out of the resin. That “something” is hardness fouling. The following metals fouling was found on the two recent cation samples from 1A and 1B:

Parameter	Primary Cation 1A	Primary Cation 1B	New Resin
Moisture, %	51%	50%	45 – 55%
Calcium, g/ft <sup>3</sup>	430	320	<50
Magnesium, g/ft <sup>3</sup>	>120	>120	<10
Barium, g/ft <sup>3</sup>	6.2	5.5	<1
Strontium, g/ft <sup>3</sup>	19	13	<1
Fe, g/ft <sup>3</sup>	9.4	9.2	<10

Action Point = 150  
Action Point 50  
Action Point 50

A group of metals were tested for but found to be less than the sensitivity of the method (1 g/ft<sup>3</sup>) and include Al, Cu, Mn, and Si. Note that the Mg test result is off scale; the test maximum for Mg is 120 g/ft<sup>3</sup>. We do not know what the actual fouling level is. RTI’s action level for Ca fouling is 150 g/ft<sup>3</sup>.

For many decades the industry has stated that high hardness fouling was “bad,” but no one knew the particular symptoms or mechanism. RTI discovered several years ago that hardness fouling prolongs the acid rinse down during the final rinse, exactly as displayed in the log plot above. The prolongation produces the exponential “tailing” and the consequences are actually felt in the primary anion. During its final rinse, water comes from the primary cation. Any extra acid present in the water will prematurely use up freshly regenerated capacity in the weak base resin, shortening its useful service time.

► RTI recommends cleaning the primary cation resin beds for hardness fouling to improve the rinse down behavior.

Part of the secondary cation's fast rinse is the cation/anion fast rinse step discussed in the anion regeneration section below.

### **Anion Regeneration**

The main steps in an anion regeneration are the following:

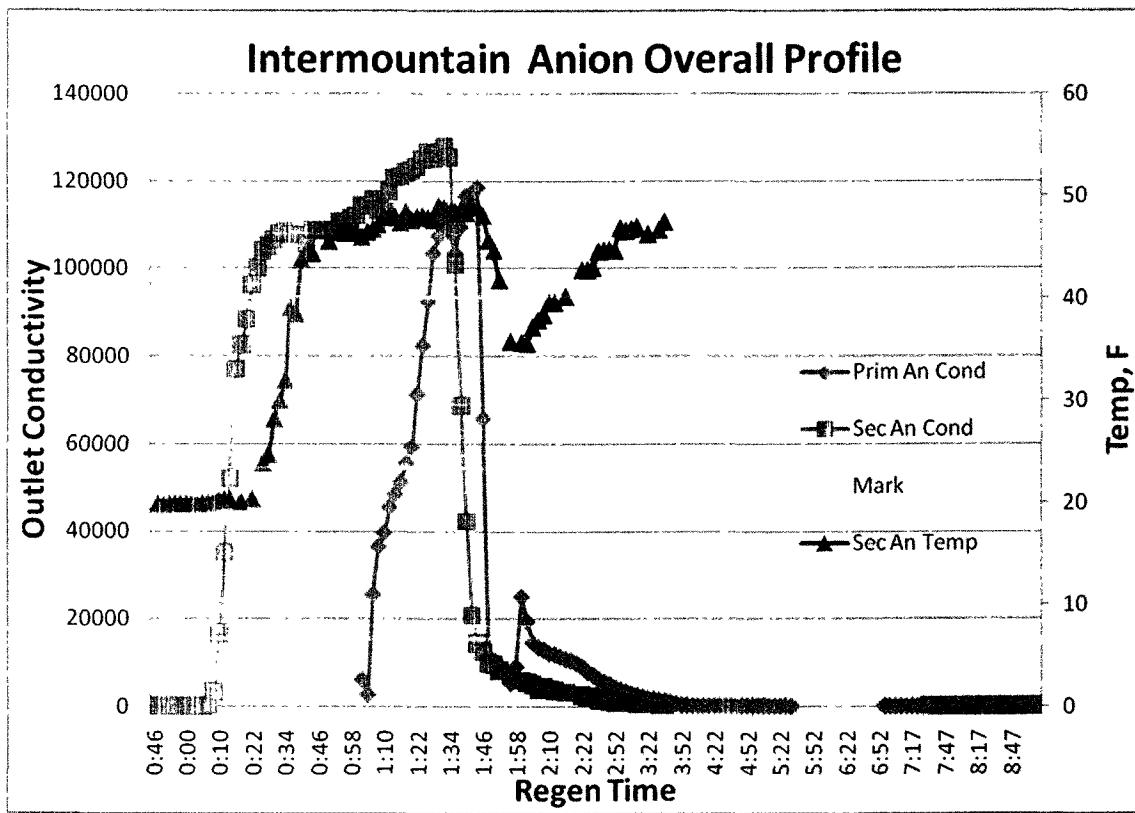
- Backwash to break up the bed
- Preheat to warm the resin bed and associated piping
- NaOH injection at 4% at 120°F
- Slow rinse
- Fast rinse
- Recycle rinse

This regen is complicated in that there are several recycle rinses. The first is within the primary cation/anion loop. The second is within the secondary cation/anion loop. The third is between the primary and secondary cations/anions. And the fourth is a mandatory total system recycle involving primaries, secondaries, and polishers.

The overall profile for the anion regenerations is the following graph<sup>1</sup>:

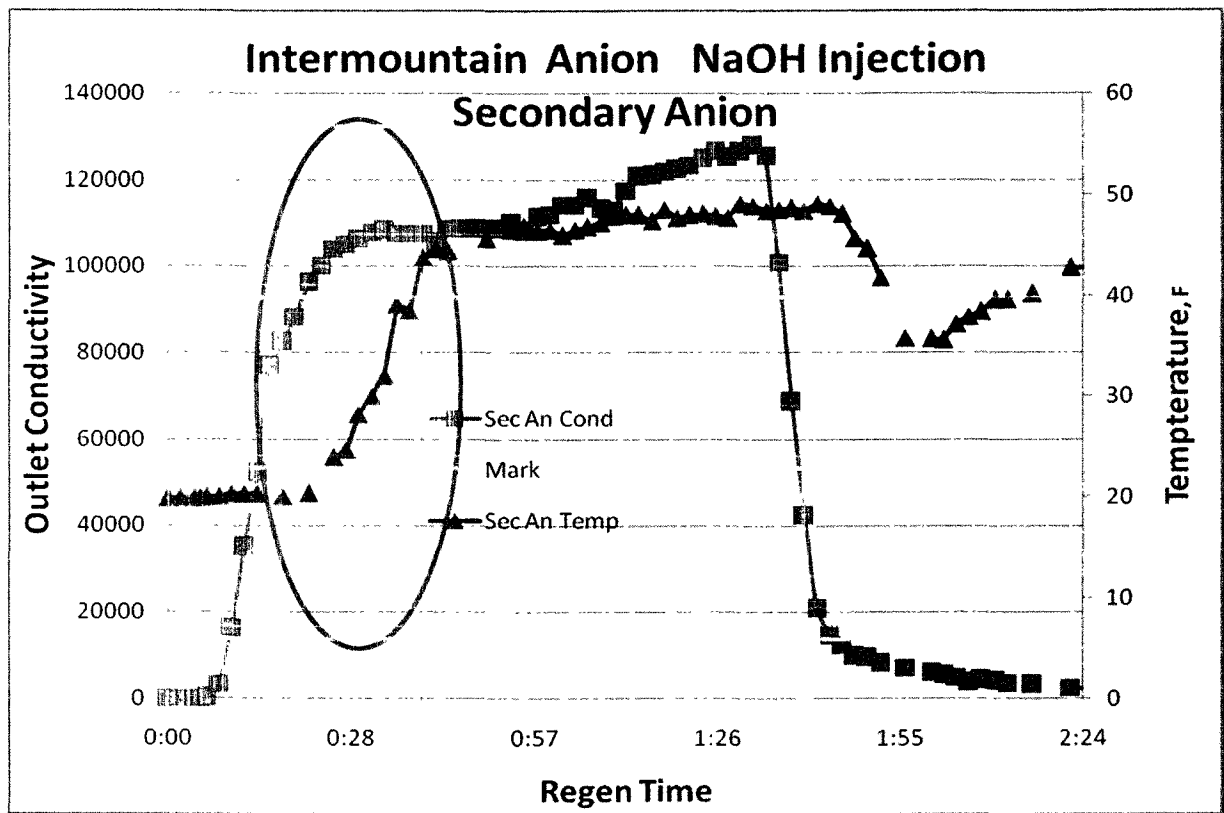
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<sup>1</sup> We apologize for the different graph style. In between working up the cation graphs and the anion graphs the author changed computers. The new computer has an updated version of Xcel which makes the "look" of the graph quite different from the earlier version used for the cations.



If we break the graph up into components and regen steps, the data become easier to interpret. Let us look at the secondary anion outlet during the caustic injection; this is a key step in the overall control of silica in this system.





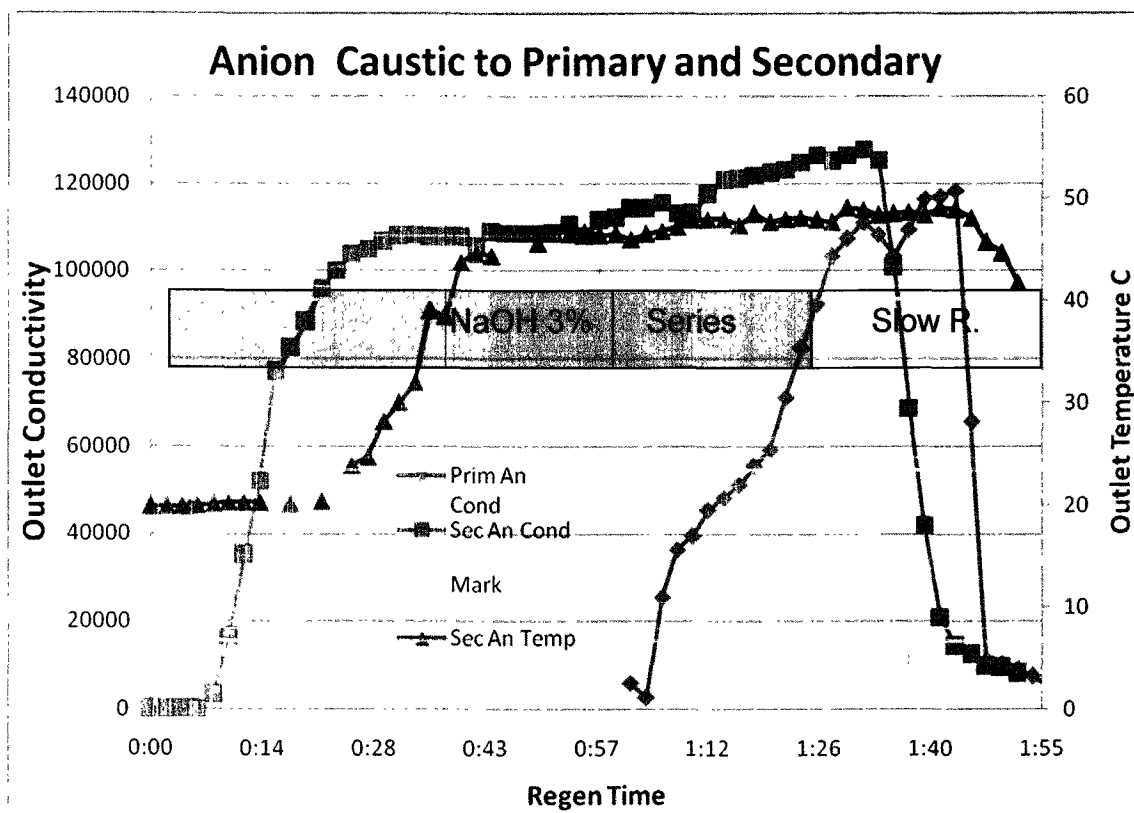
(1) The first conclusion from the data is that the lack of a bed preheat impacts the effectiveness of the regeneration. Note the time it takes for the outlet temperature to reach 48°C (about 118°F). The delay in reaching the inlet temperature is highlighted in the blue oval. This means that fraction of caustic within the oval, some 33%, is not being delivered to the strong base resin at the stipulated temperature. This means the overall investment in caustic is not realizing its full potential in terms of silica removal from the resin, which directly translates into next run capacity and silica leakage.

► Incorporate a secondary anion bed preheat step. This requires the injection of heated dilution water for some 40 minutes. The water is sent to waste.

On the other hand, if the current performance of the demin system is considered acceptable, no change is needed in the regen program.

(2) At its peak, the effluent conductivity reached 130,000  $\mu\text{S}$ , equivalent to just over 2% NaOH concentration.

A graph identifying the regeneration steps is the following:



(1) Note the slight delay at the beginning of the caustic injection (where the left edge of the green NaOH box does not touch the Y-axis. Although regen time zero is usually the start of the caustic pump, in this case the pump cannot start until the dilution water reaches the target temperature of 120°F. This took several minutes. Had there been a preheat step, the dilution water would already have been at temperature and the caustic injection would have started immediately.

(2) The caustic injection is divided up into two segments. The first part of the injection, corresponding to the left-hand division in the green caustic box, injects only to the secondary anion. This fraction of caustic is laden with silica and were it to be injected into the primary anion, the super-efficient regeneration by the weak base would neutralize the caustic, causing the silica to precipitate within the weak base resin bed. This usually occurs as white needles, which clog the bed and cause extensive channeling. This initial fraction of caustic is sent to waste.

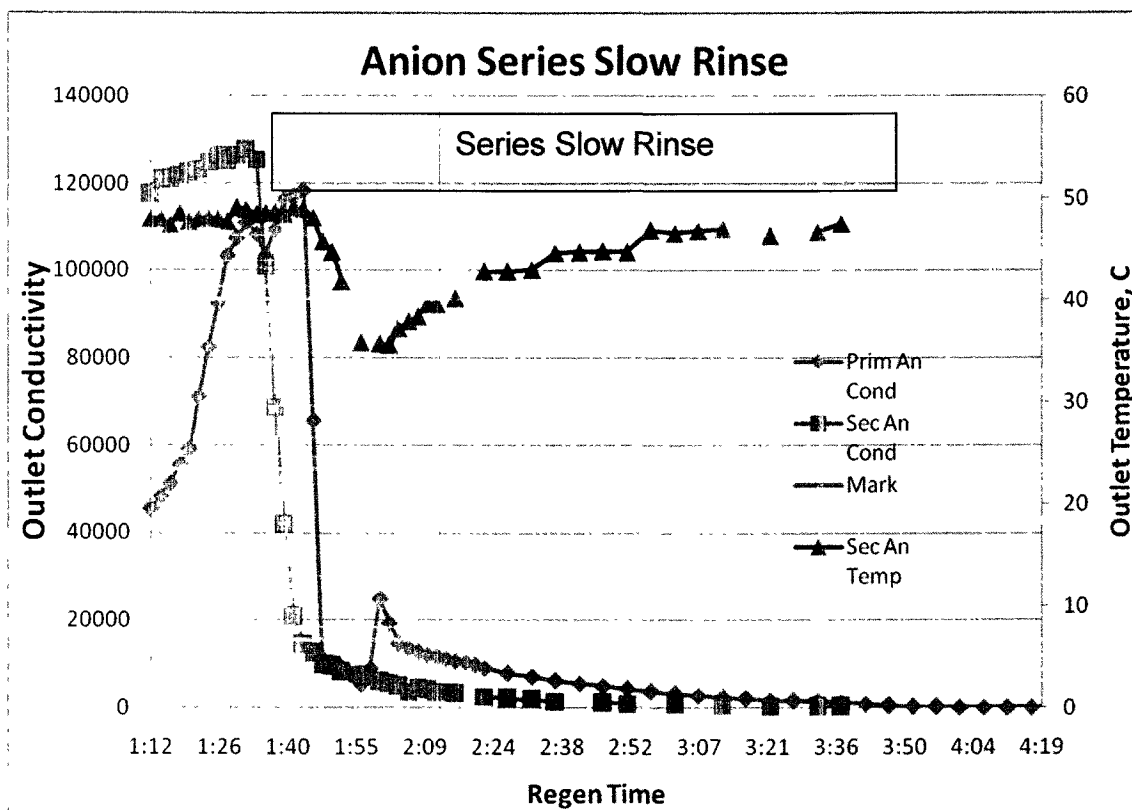
It is followed by the series injection of caustic, the right-hand part of the green caustic box, in which the caustic from the secondary anion is injected into the primary anion. The weak base is regenerated "for free," using waste caustic from the secondary. This is one of the advantages of thoroughfare regeneration.

(3) The lab technician was reported Baumé readings of 3.0 – 3.2% caustic, the outlet conductivities do not bear this out. At the highest reading from the secondary anion, some 128,000  $\mu$ S, this corresponds to a caustic concentration of 2.1%.

Although the dilute caustic flow is within optimal range, there could be a caustic distributor out of alignment in the secondary anion, causing caustic to inject upward into the water-filled head space above the bed (much like the acid situation earlier). An inspection of the spray pattern of the caustic inlet should be done.

► With the vessel drained to bed level, initiate caustic dilution water injection (no caustic!) and observe the spray pattern of the caustic inlet distributor for anomalies.

The next step is the 140-minute series slow rinse:



(1) This is the longest slow rinse the author has ever seen. The objective of the slow rinse is to continue the movement of the regenerant "plug" through the bed at the required slow flow rate. At the end of the caustic injection, if the unit went directly into fast rinse, the last fraction of caustic would speed through the bed, resulting in an ineffective regeneration. To continue the slow movement, a slow rinse is used.

The slow rinse is dilution water minus regenerant. In the anion case, warm DI water is used – at the same flow employed for the main caustic injection step. The step is considered over when the conductivity profile shows that the bulk of the caustic has left the primary anion vessel and both beds are now ready for fast rinse.

Note in the above case how the conductivity drops quite steeply once the slow rinse is initiated. The bulk of the caustic has left easily by 25% of the current time. This corresponds to 35 minutes, well within range of normal industry practice of 40 minutes.

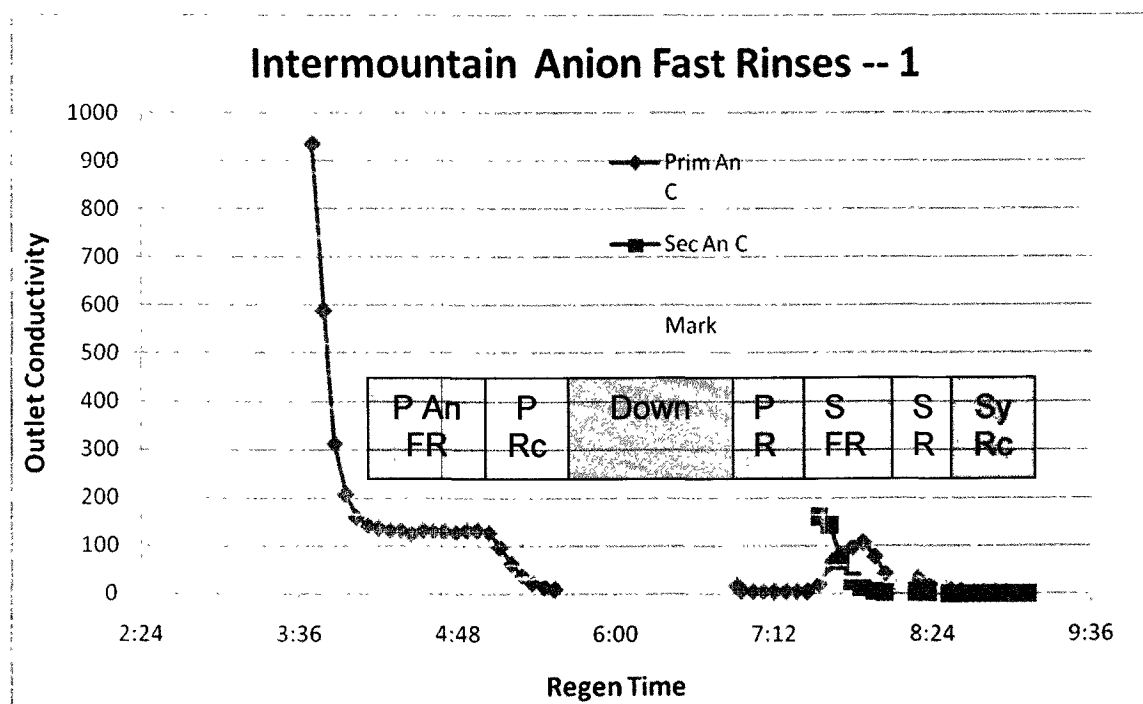
Because two vessels have to be “cleared” of their caustic, we recommend being conservative in reducing the duration of this step and would suggest 60 minutes.

- Reduce anion series slow rinse from current setting of 140 minutes to 60 minutes.

Note that with this change, the anion leg might have to wait for the cation leg, rather than the current programming in which the cation waits for the anions to catch up. The key step requiring the cation wait is the overly long 140-minute slow rinse.

### Anion Fast Rinses

There are a series of anion fast rinses, which also include exchanger recycle rinses. They are shown on the following series of graphs, each one of which uses a tighter expansion of the Y-axis to show small details with low conductivities.



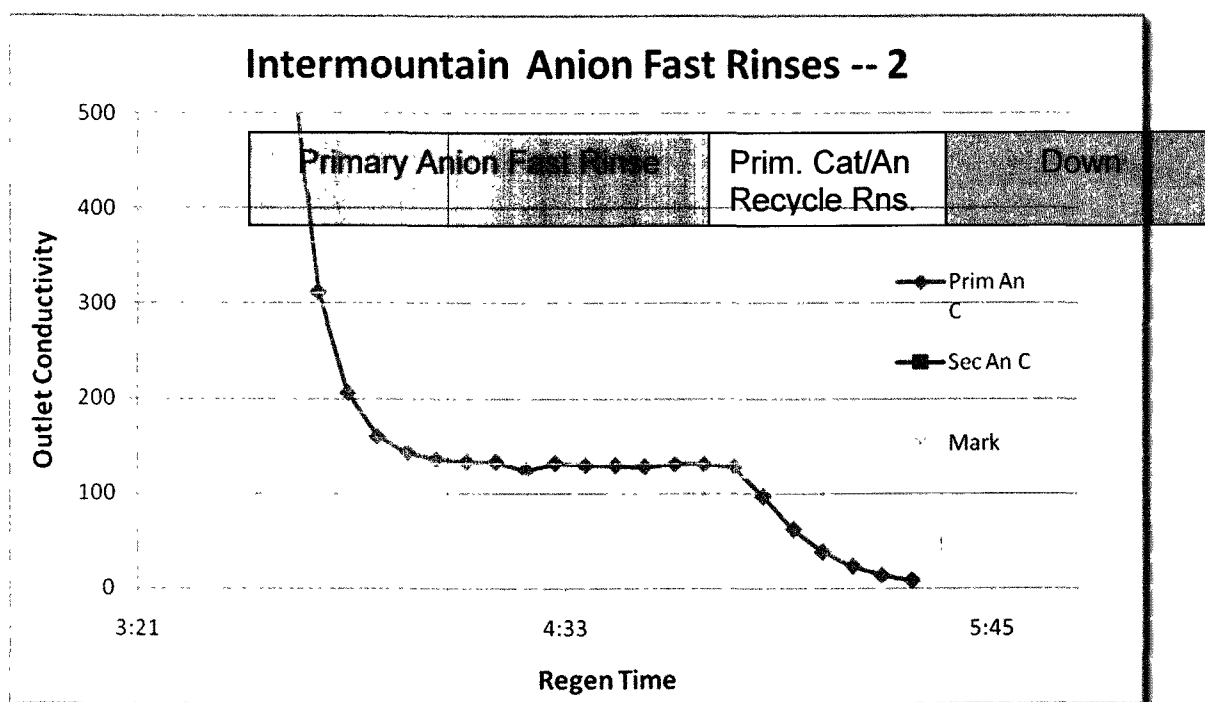
The step legend is very busy and titles have to be abbreviated. Here is their identity, using blue boxes for the primary and magenta boxes for the secondary:

Abbreviation	Step	Time
P An FR	Primary Anion Fast Rinse	75 min.
P Rc	Primary Cation/Anion Recycle Rinse	40
Down	System shut itself down	90
P R	Primary Cation/Anion Recycle Rinse – continued	40
S FR	Secondary Anion Fast Rinse	30
S R	Secondary Cation/Anion Recycle Rinse	40
Sy Rc	Primary/Secondary Recycle Rinse	40

The system shut itself down for the third time during the primary recycle rinse. It was extremely difficult to restart. A programming expert was called in. Confusion arose because the numbering of the regeneration steps in the Modicon does not correspond with the numbering of the steps on the control screen. It seems the Modicon does not count the three settle steps after each backwash at the beginning of the regeneration as discrete steps, whereas they are listed and numbered on the control screen.

► Remove the disparity between the numbering of the regeneration steps on the control screen and the Modicon program.

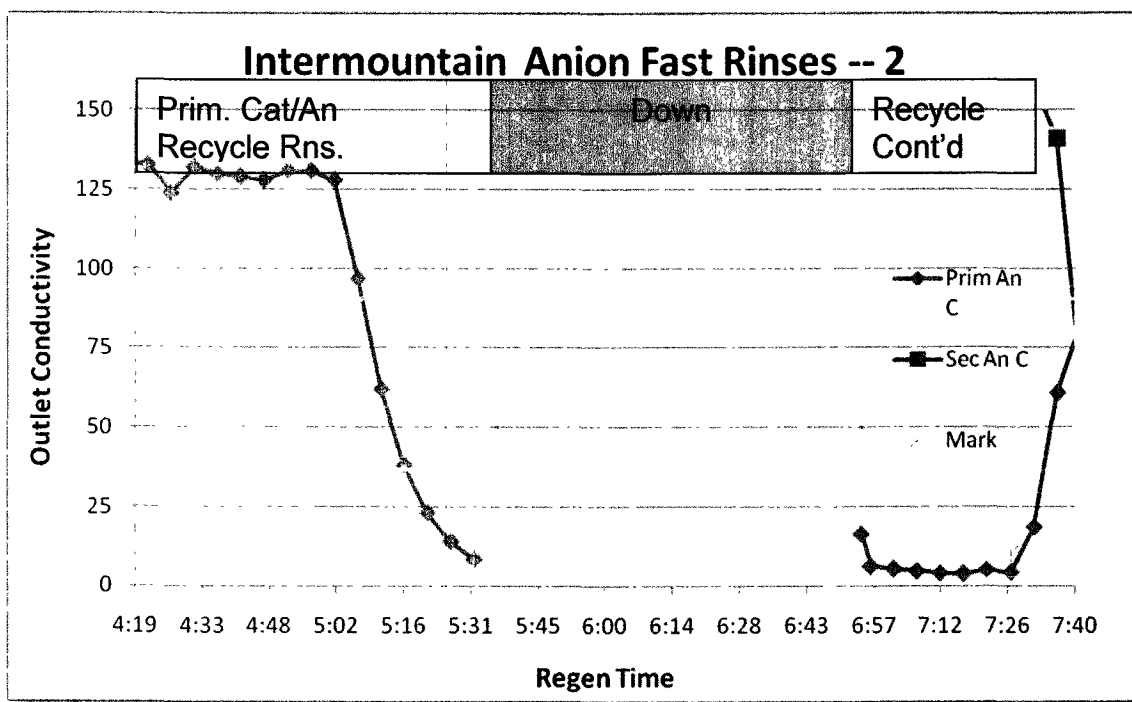
The first item of concern is the long primary anion fast rinse:



(1) It is clear from the above data that the anion fast rinse plateaus out about a third of the way through the step. Thus, this rinse could be terminated one third of the way through its current time of 75 minutes.

► Reduce primary anion fast rinse from current value of 75 to a new setting of 30 minutes.

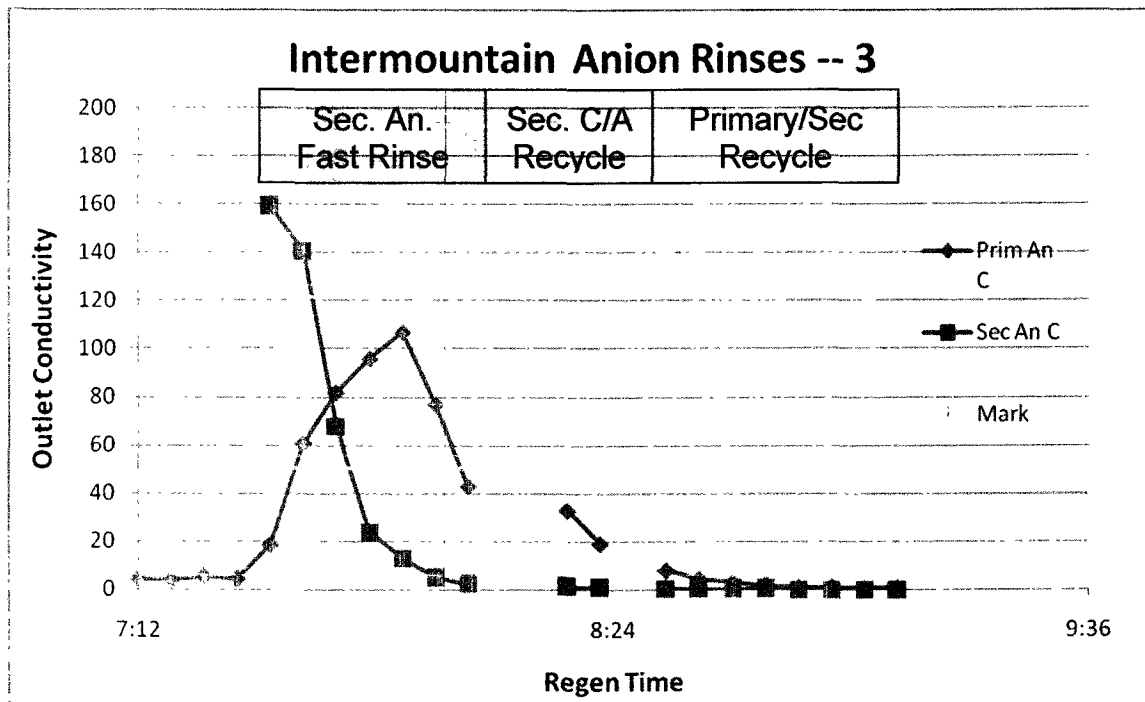
(2) The system then goes into a primary exchanger recycle rinse, cycling water from the primary anion (degasifier sump) back to the cation inlet for some 40 minutes. We are not sure of the value for this step. Clearly the conductivity goes down very low. This is shown in the following graph, which picks up the recycle rinse after the shutdown.



The slight rise in conductivity when the recycle rinse resumed at the end of the shutdown is always seen in demins during rinse. When flow is stopped, diffusing acid ions still leave the resin and accumulate in the extra-resin water. When flow is resumed, the first fraction of water leaving the vessel always has an elevated conductivity. The data show the rinse returned to normal kinetics quite rapidly, which is expected.

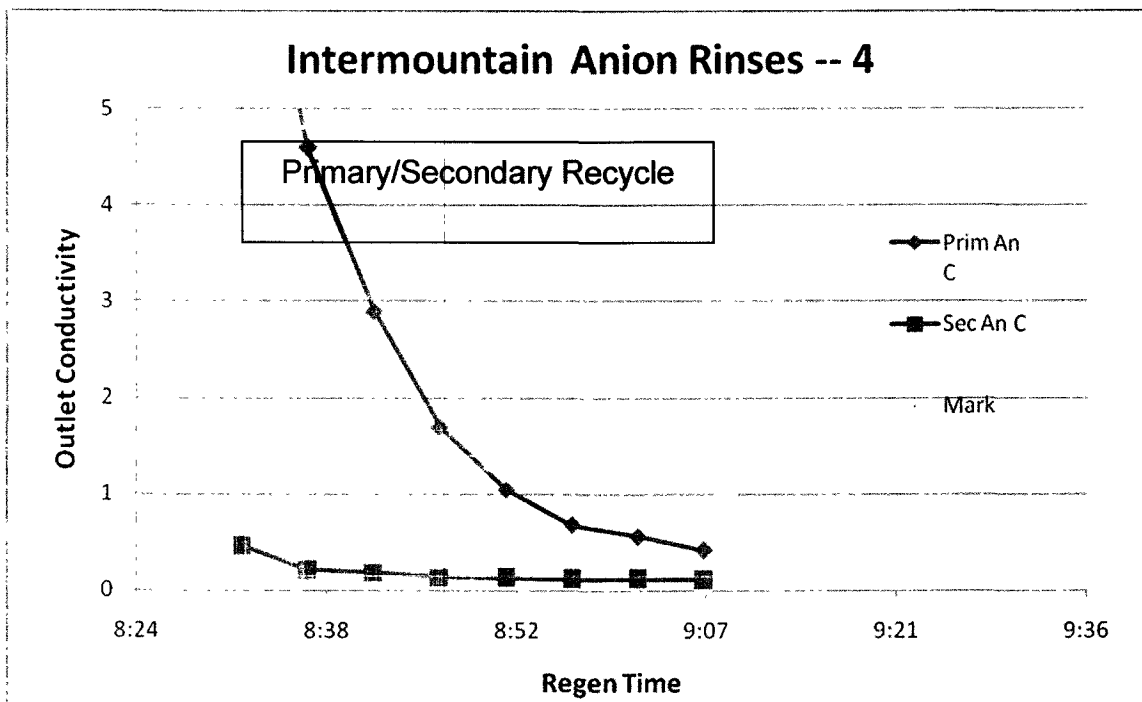
#### Secondary Anion Rinses

After the primary cation/anion has recycled to a conductivity target of 10 or so, the secondary anion is programmed to have a fast rinse and then an internal secondary recycle. These are shown below:



- (1) The secondary anion fast rinse is timed for 30 minutes, which appears good.
- (2) Then the program calls for a secondary exchanger (cation and anion) recycle rinse. We do not see the benefit from a conductivity standpoint for this step. The anion outlet conductivity is already excellent and the system could benefit from going directly into primary/secondary recycle, the last step of the regeneration.

The final conductivity values for this regeneration are shown below:



By the end of the primary/secondary recycle rinse, conductivities out of both anions were truly excellent.

If the system were needed on-line, it cannot go into service without a “mandatory” 40-minute total system recycle, primaries, secondaries, and polishers. This is a safety precaution in the absence of polishing mixed beds.



## Inspection 9/9/08

### Mechanical

This demin system is, frankly, one of the most soundly built systems we have ever seen. The vessels, vessel supports, piping, and valving are all of high quality with a thickness "for the millennium." Only diaphragm valves were used, some of them quite large. In addition, the system has been well maintained. There is no evidence of corrosion. Vessels, valves, and piping look like they were painted somewhat recently (no chipping or flaking). We would expect several more **decades** of reliable mechanical integrity from this system, if the current maintenance practices are continued.

There is a lot of space between vessels and trains. Some minor coal dust can be seen on some parts of the equipment, but, in general, the area is surprisingly clean for a coal-fired utility. Tanks are clearly identified, key piping manifolds are labeled.

Inlet and outlet pressure gauges need calibration, followed by a temporary recording of system DP values (along with flows).

RO is on second floor (preceded by 10  $\mu$ /1 $\mu$  cartridge filters, along with vacuum D/Gs, and acid and caustic bulk storage tanks. On the second floor, the DI caustic dilution water is electrically heated; there appears to be an on-going problem with heating elements.

The original (pre-RO) well water system has several large cartridge pre-filters ahead of the demins. The RO injection point is between the filter outlets and the demins, creating a deadleg when on RO.

The acid and caustic dilution stations show good maintenance. One expects more corrosion here due to the nature and concentration of the chemicals, but good maintenance is in evidence. There are two separate acid and caustic dilution systems, one for each demin train. This is a rare design; trains usually share acid and caustic dilution equipment. Don Smith says this evidences the original design philosophy of the plant: complete redundancy of peripherals. Only one demin train is needed to "hold the plant." Two would be needed during a system refill, for example, after a boiler was drained for repairs or cleaning.

### Vessel Inspection

With the correct volume of resin installed in a vessel of this design, the top of the resin bed should be 4 – 5" below the regenerant inlet header. Results of inspections of the resin beds show the following:

Vessel	Identity	Bed, Inches Down from Regen Header	Corresponding Cubic Feet	Comment
<b>10/27/06 Inspection of A Train</b>				
1A Prim Cat	Strong Acid	4"		Correct
2A Prim An	Weak Base	36"	136 CF	Huge Error
3A Sec Cat	Strong Acid	7"		Low, but OK
4A Sec An	Strong Base	25"	128 CF	Huge Error
5A Pol Cat	Strong Acid	5"		Correct
6A Pol An	Strong Base	6"		Low, but OK
<b>3/26/07 Inspection of B Train</b>				
1B Prim Cat	Strong Acid	7"		Low, but OK
2B Prim An	Weak Base	7"		Low, but OK
3B Sec Cat	Strong Acid	8.5"		Marginal
4B Sec An	Strong Base	5"		OK
5B Pol Cat	Strong Acid	10"		Too low
6B Pol An	Strong Base	7"		Low, but OK

Regarding the loss of weak base resin, this is not uncommon. Of the four resin types, the weak base is the lightest in density, and if measures to accurately control the backwash flow rate are not in effect, weak base resin can easily be lost by a slight change in backwash flowrate. Likewise, the loss of strong base resin is more common than the loss of cation resin, again due to density differences. The latter appear to have the correct volume, except for the 5B Polisher Cation, which was definitely low on resin when the measurements were made in March.

Cindy Jones in the lab confirmed that the missing volumes of primary and secondary resin were replaced with new materials.

There was a comment on the 3/26 inspection sheet: "oily sheen – degasifier." Cindy confirmed that the sheen was seen floating on the water above the 4B resin sample. Oil can be devastating in a resin (and membrane) demineralizer. Only the slightest coating of oil on the beads is sufficient to *shut down* ion exchange, which is directly dependent on free diffusion of ions in and out of the beads.

### Resin Analysis

We are fortunate to have a recent round of resin analyses from the entire system. The A Train was sampled in November of 2006; the B Train in March of 2007. We offer our opinion of the resin test results, which track that of MECO, the company performing the resin analysis.<sup>2</sup>

<sup>2</sup> MECO is Maintenance Engineering Co, located in Houston, TX. They are a Master Distributor for Rohm and Haas resin, meaning they are the only authorized Rohm and Haas supplier in the Southwest.

### A Train, November, 2006

Vessel	Resin ID	Test Results and Comments	Further Comments
1A Prim Cat	Amb. IR-120	Moisture very good; heavy Fe fouling.	<b>Need Ca fouling</b>
2A Prim An	Mix of A2XMP and IRA-94 (mostly 94)	Capacity good, but heavy fouling with silt and fines	Thermax is a Tier Three supplier; MR resin not needed
3A Sec Cat	Amb. IR-120	Moisture excellent; lot of cracked beads	Not as bad as it sounds
4A Sec An	Marathon A	Excellent capacity, very light organic fouling, some Fe	UPS resin not needed
5A Pol Cat	Amb. IR-120	Capacity excellent, minor cracked beads	None.
6A Pol An	Amb. IRA-402	Excellent capacity, essentially no fouling. High cracked beads.	Not as bad as it sounds.

### B Train, March, 2007

Vessel	Resin ID	Test Results and Comments	Further Comments
1B Prim Cat	Amb. IR-120	Moisture very good; heavy Fe fouling.	<b>Need Ca fouling</b>
2B Prim An	Mix of A2XMP and IRA-94 (mostly 94)	Capacity good, but heavy fouling with silt and fines	Thermax is a Tier Three supplier; MR resin not needed
3B Sec Cat	Amb. IR-120	Moisture excellent; lot of cracked beads	Not as bad as it sounds
4B Sec An	Marathon A	Excellent capacity, very light organic fouling, medium Fe. Surface debris noted.	UPS resin not needed
5B Pol Cat	Amb. IR-120	Capacity excellent, minor cracked beads. Slightly turbid backwash.	None.
6B Pol An	Amb. IRA-402	Excellent capacity, essentially no fouling. High cracked beads.	Not as bad as it sounds.

There is a strong symmetry between the two sets of results. This means the trains have been treated the same over the years.

The results of the analysis of the 1A and 1B recent cation samples were reported earlier.

## System Control

The demin system used to go to 560K throughput before RO was installed last year. With the RO in place, the plant does not have new throughput target yet. They have gone to 17 MM for the longest run. Don Smith thinks 10 MM likely better.

► Hold off settling on a designated target for the demins until a silica profile is obtained. (See below.)

Conductivity on Vac D/G outlet. There are 2 meters, one for normal control, one for mandatory recycle. The normal service control unit will **trip** the demin system at 35  $\mu$ S. The meter on recycle will (only) **alarm** if recycle does not get down to 30  $\mu$ S in the 40-minute time frame.

We were fortunate to have access to a recent round of water analyses from the plant, courtesy Norm Hess. The samples were taken on 8/13/08, and are re-organized in the table below. All values in ppm except pH and conductivity

Train:		A TRAIN Demin					
Vessel:	RO Out	Prim C	Prim A	Sec C	Sec A	Pol C	Pol A
Analysis:							
pH	6.5	4.4	N/A	N/A	N/A	5.5	N/A
Conduct.	8.9	5.3	<3	<3	<3	<3	<3
Cl	1.2	1.0	<0.5	<0.5	<0.5	<0.5	<0.5
Na	1.9	0.098	0.098	0.002	0.003	<0.002	0.002
SiO <sub>2</sub> ,	1.5	1.6	1.6	1.6	<0.05	<0.05	<0.05
T. Hard.	0.93	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
M Alk	3.3	<2	N/A	<2	N/A	<2	<2
Fe	0.007	<0.002	<0.002	<0.002	<0.002	0.005	<0.002
		B TRAIN Demin					
		Prim C	Prim A	Sec C	Sec A	Pol C	Pol A
pH		4.4	N/A	5.3	N/A	5.6	N/A
Conduct.		6.2	<3	<3	<3	<3	<3
Cl		1.2	<0.05	<0.05	<0.05	<0.05	<0.05
Na		0.071	0.072	0.010	0.010	<0.002	<0.002
SiO <sub>2</sub> ,		1.5	1.5	1.5	<0.05	<0.05	<0.05
T. Hard.		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
M Alk		<2	N/A	<2	N/A	<2	N/A
Fe		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002

Removal of main contaminants: (main contaminants are those which can directly affect boiler chemistry)

(1) Na: reduced to just under 0.1 ppm through primary cations. Then to 0.002 (limit of detectability) in Train A, 0.010 in Train B secondary cation. Then to less than detectable (<0.002) in polisher cation effluent.

(2) Cl: reduced to limit of detectability (0.5 ppm) in primary anion (weak base). This is as it should be, although the sensitivity at 0.5 is not great.

(3) SiO<sub>2</sub>: effectively removed in secondary anions to limit of detectability (0.05 ppm), although this sensitivity is also not great.

(4) Hardness: the very low leakage from the RO is quite effectively handled by the primary cation, which is as it should be.

Removal of secondary contaminants: (secondary contaminants would have only a minor effect on boiler chemistry)

(5) Fe: the very small amount coming in from the RO appears to be effectively removed in the primary cations to the limit of detectability, <0.002 ppm, except for the anomalous value in A Train polisher cation, 0.005 ppm. Caution: sampling and analysis at the single digit ppb level for any element is very challenging; anomalous results are often obtained unless great efforts are expended for proper sampling technique.

(6) M-Alkalinity: appears as 3.3 ppm in RO outlet. Need for vacuum degasifier is highly doubtful, unless it contributes to control of O<sub>2</sub>. The secondary anion can easily handle this very light alkalinity loading.

► NEED Well Water (inlet to RO) analysis.

In high purity water (such as that of the secondary demins and on) conductivity becomes difficult to measure. It is almost impossible to measure accurately with off-line sampling; on-line probes are mandatory. In addition, high purity water is often at the very "end of the scale" for non-digital conductivity meters, in which the scale often ends at 0.1. The conductivity of ultrapure water is 0.056 µS. Newer, digital conductivity meters are capable of reading 0.056 µS accurately.

### **Vacuum Degasifier Monitoring**

Don Smith requested advice on monitoring the vacuum degasifier. The Vac D/G does an excellent job in removing CO<sub>2</sub>, one of its main functions. CO<sub>2</sub> is very difficult to measure in a water system under normal ppm concentrations. At the level expected in the D/G effluent, which would be ppb, it cannot be measured with field sampling.

The Vac D/G also removes oxygen, and there are very good tests for O<sub>2</sub> at the ppb level. The problem is atmospheric contamination. A “flowing cup” sampling technique is needed:

- Obtain a liter jar or plastic beaker
- Fix an oxygen-impermeable sampling line to the D/G sump outlet
- Put the end of the tube at the bottom of the jar
- Let the sample run for several minutes
- Insert the O<sub>2</sub> sample tube down at the bottom of the jar
- Break the tip
- Carefully mix with no further air intrusion

This will establish some baseline of O<sub>2</sub>, which can also be correlated with vacuum measurements.

### **Regeneration Control**

There is a good (but old fashioned) system display panel (valve lights, etc. superimposed on drawing of system). There are step timers for acid and caustic, with the values repeated to water plant control room screens.

NOTE: screens in the water plant control room are for display only; no control can be exercised. All control is “manual,” at the board, except for the control exercised by the ladder logic regen controllers (likely original). In general, all peripheral systems at this station are under local, manual control. Only the boiler and turbine are under DCS.

During the regeneration, lab techs measure Baumé and then adjust acid and caustic valves manually. The flow meters are likely out of calibration. This could lead to the high level of inconsistency seen in the regeneration study.

The plant rotates operators on complicated schedule. An operator might see the water plant once in 12 months. The rotation schedule is not going to change. One solution to preserving water quality and efficiency is more automation of the system.

► Refurbishing the control panel with a newer PLC would normally be recommended. However, Don Smith reports that the I&N technicians at the plant are comfortable with the Modicon and do not want to relearn another control logic.

### **System Changes with RO**

How the strong cation and anion resins react to inlet chemistry is somewhat complicated. When the RO was installed, the inlet chemistry for the demins changed substantially, not only in TDS, which is obvious, but also in proportional chemistry. The following table compares the pre- and post-RO inlet chemistry:

Parameter	Pre-RO Inlet (average of 5)	Post-RO Inlet (sensitivity)
pH	7.9	6.5
Conductivity, $\mu$ S	419	8.9 (3)
M-Alk, ppm as $\text{CaCO}_3$	114	3.3 (3.0)
Total Hardness, ppm as CC	84	0.93 (0.02)
Sodium, ppm AI	55	1.9 (0.0002)
Chloride, ppm AI	46	1.2 (0.05)
Sulfate, ppm AI	32	<0.5 (0.05)
Silica, ppm AI	40	1.5 (0.05)
Fe, ppm AI	0.4	0.007 (0.002)

On the cation side, there is more Na now than hardness by a factor of 2; it used to be the opposite by a factor of just shy of 2. An increase in percent Na increases the capacity of the resin for all cation impurities, but also raises the Na leakage.

On the anion side, the inlet silica was very high, not too far from inlet chloride. The ratios are still similar in the post-RO water, but the overall inlet silica level is quite low. As a percentage, however, there has been an enormous change. In the pre-RO well water, silica was only 11% total anions (on a ppm as  $\text{CaCO}_3$  basis). In the post-RO water, silica is fully 32% of total anions.

### **Silica Behavior with RO Pretreatment**

Over the years we have witnessed many system changeovers as customers add RO ahead of their resin-based demineralizers. The ostensible reason was to reduce chemical consumption and handling of acid and caustic, and this objective was almost always met. Most clients, however, are unaware of the changes in silica dynamics within the resin part of the system when fed a low TDS inlet with a high silica percentage. In addition, there are no standard “engineering curves” available from the resin suppliers to address this unusual chemistry situation.

The most important change RTI has seen is that the silica breakthrough is very much drawn out in time, rather than being abrupt, as it normally is with a high TDS, low percent silica inlet. This means the polisher anion is likely seeing a higher silica loading than design with post-RO operation. Since the loading on the polisher anion is virtually 100% silica, there is a further change in its performance, with the same kind of drawn-out silica leakage.

The truest test of any aberration in the polisher anion’s chemistry is the boiler silica levels. The lab reports no problems with this, either pre- or post-RO. The point is not moot, however, since we are trying to identify an optimal end-of-run point for the primary/secondary part of the system, which will impact the polisher loading. The silica profile project proposed below will nail this down and resolve the issue.

### Special follow-up study (with Norm Hess)

Daily samples from Sec An outlet, from the beginning of the run to the very end, which must include a conductivity break (important to get to this point). This will firmly establish the silica leakage and silica exhaustion profiles for the system, and furnish direct guidance as to setting an appropriate throughput target for the primary and secondary resin beds. Since B Train has been freshly regenerated, we suggest sampling this train.

► Special follow-up study (with Norm Hess). B Train service run: let the train run for a week or so, and then initiate daily sampling from Primary Anion (or degas outlet) and Secondary Anion. Analysis to include:

- Ppb SiO<sub>2</sub>
- Ppb Cl
- Ppb Na

No other values (such as pH, alkalinity, etc.) are needed from the lab. However, in addition, when the samples are taken, **the current conductivity values on the B Vacuum Degasifier and B Secondary Anion should be recorded from the display screen in the water plant control room.** These values will prove more accurate than the lab-measured conductivity in a shipped sample of relatively pure water. The lab sensitivity is 3 µS, which is too high to be useful for this project.

Once we have determined the silica and conductivity breakthrough profiles, we can revisit the acid and caustic dosages to the primary and secondary resins.

Future work might include the polisher beds, but they are so infrequently regenerated that this is very minor. Any consideration of the polisher bed regen frequency can be eliminated by regenerating them once a year, rather than every two or three years.

### Caustic Quality

We received a Certificate of Analysis for a delivery in November of 2006. The plant is under the impression they are using rayon grade caustic; that is not the case. Below is a table comparing rayon grade against the 2006 CoA. The supplier is Basic Chemicals Co, a division of Univar, out of Salt Lake City. The actual manufacturing plant appears to be in Wichita, KS.



Parameter	Unit	Acceptable Value	Rayon Actual	
			Max. Specification	
			Rayon Grade	Basic Chemicals
Total Alk as Na <sub>2</sub> O	Weight %	38.6		39.6
OH Alk as NaOH	Weight %	49.7		51.0
NaCl	Weight %	1.00	0.1	1.20
NaClO <sub>3</sub>	Weight %	0.11	0.0005	0.30
NaClO <sub>3</sub>	Weight ppm	1100	5	3000
Fe	Weight ppm	2.3	X	9.0

► The plant should check with purchasing regarding the price and grade of the caustic being used here. The plant should verify they are not paying for rayon grade, which this caustic clearly is not.

The history behind the use of rayon grade caustic is that the resin manufacturers for years have recommended its use to preclude long term problems with the use of their resins. Many subsequent field tests and published technical papers have established that much higher levels of sodium chlorate can be used than appear in rayon grade.

## Appendix 1

### Ion Exchange Background Concepts

We characterize the chemical performance of ion exchange resins by two factors:

- Leakage, which determines water quality
- Overall capacity, which determines throughput

Ion exchange is not perfect. Leakage is the contamination level coming out of the resin throughout the run. It is usually at a very low, but measurable level, typically ppb. Breakthrough or exhaustion is the sudden appearance of a wave of impurity at the end of the run; this determines capacity. It limits the run because the water no longer meets target specifications and the units must be taken off for regeneration.

The element or compound which leaks is also responsible for the breakthrough at the end of the run. Thus, Na leaks during the cation run and will suddenly increase quickly at the end of the run. Silica normally leaks during the anion run and will suddenly increase quickly at the end of its run. A quirk of anion chemistry, however, allows that the anion unit can continue to be operated “past the silica break,” as it is called. There will be a subsequent, secondary break on chlorides, which manifests itself as a conductivity break.<sup>3</sup>

From an activity standpoint, there are four chemical classes of resins, which can be broadly characterized in the following table:

Resin Classification	Capacity	Leakage
Weak Acid Cation Exchanger	Fixed	(none)
Strong Acid Cation Exchanger	Variable	Variable (Na)
Weak Base Anion Exchanger	Fixed	(none)
Strong Base Anion Exchanger	Variable	Variable (SiO <sub>2</sub> )

Briefly, a **weak acid** cation exchanger only does a particular kind of cation chemistry: it removes hardness equal to inlet alkalinity. It has a fixed capacity. There is no leakage; the resin either handles the hardness/alkalinity or it does not. Any excess hardness or alkalinity is not removed, but it is not considered leakage. There is no reaction with Na.

The **strong acid** cation exchanger does all possible cation-related chemistry, including hardness and alkalinity removal, and Na. It leaks a low level of Na, and there is a sudden increase in Na at the end of the run.

<sup>3</sup> For anyone who might be interested, there is also a secondary break on the cation side after the Na break. Hardness in the form of Mg ions will breakthrough. The unit is no longer operating as the cation component of a demineralizer at this point. It is actually a softener, which uses the same strong acid cation resin as the demineralizer, except that it is regenerated with brine and routinely operates to the hardness end point. (There is no Na endpoint since with brine regeneration all the active sites are in the Na form to begin with.)

The **weak base** resin removes only chlorides and sulfates. There is no reaction to alkalinity (CO<sub>2</sub>) and silica, which proceed through the vessel unchanged. The resin has a fixed capacity for chlorides and sulfates and there is no leakage. Its inability to handle CO<sub>2</sub> and silica is not considered leakage. At the end of its run, there is an abrupt increase in chlorides in the water, not by way of a leakage increase, but by way of having used up all the capacity.

The **strong base** resin removes all anions, including chlorides, sulfates, silica, and any residual CO<sub>2</sub>. During the run, a low level of silica “leaks” from the vessel. At the end of the run, the silica level increases abruptly and many systems end the anion run at this point. There is a minor impact on conductivity during the silica break. Some systems, including IPSC, continue to operate the anion “past the silica break,” as it is termed. As mentioned earlier, there will be a secondary or subsequent break on chloride, which produces a large change in conductivity. The IPSC strong base (secondary) anions are operated to the conductivity break (35 µS in the degasifier outlet). This has some undesirable consequences, as discussed below.

Since the strong base resin can do all anion contaminant removal, and the weak base can only remove chlorides and sulfates, the weak base resin must be upstream of the strong base resin in any design.

As indicated in the preceding table, the chemical performance of **strong acid** cation resins and **strong base** anion resins is variable. Resin chemistry is sensitive to several chemical factors:

- Overall dosage of acid or caustic (usually expressed in lbs 100% regenerant per cubic foot, #/CF)
- Inlet chemistry
- Regenerant strength
- Regenerant temperature (anion only)

Each factor impacts on the performance in different ways:

Factor Changed (say, increased)	Impact on Capacity	Impact on Leakage (Na from cation; silica from anion)
Dosage, lbs/CF	Increases	Decreases
Inlet chemistry	(Complicated)	(Complicated)
Regenerant strength	Increases, up to a certain point	Increases, up to a certain point
Regenerant temp (anion only)	Increases, up to a certain point	Decreases, down to a certain point